RF Backgrounds - Update

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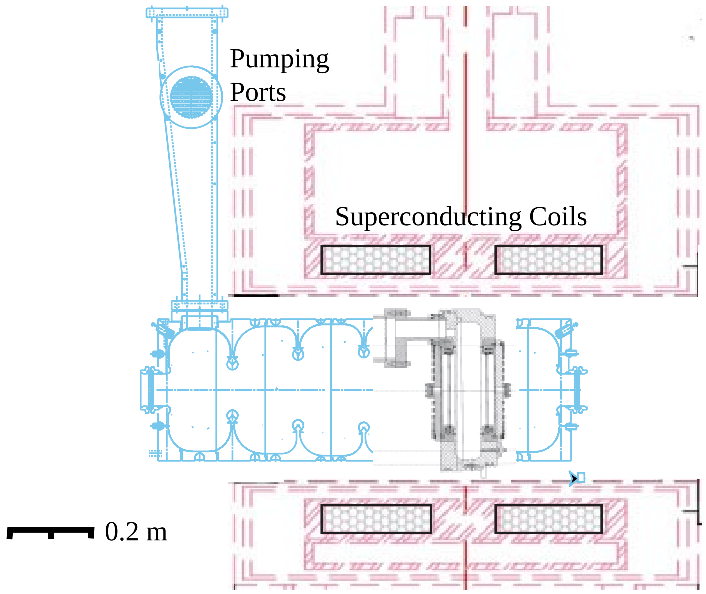
NUFACT03 / MC Meeting / MICE Collaboration
Columbia University
June 5 -14, 2003

Muon Collaboration

Outline



An active program: Two cavities, many surfaces

What have we learned?
  A new breakdown model
  Magnetic fields can be problems
  Be works!!
  We developed new techniques, produced new data

What do we need to know?
  How to control the copper that splashes on the Be.

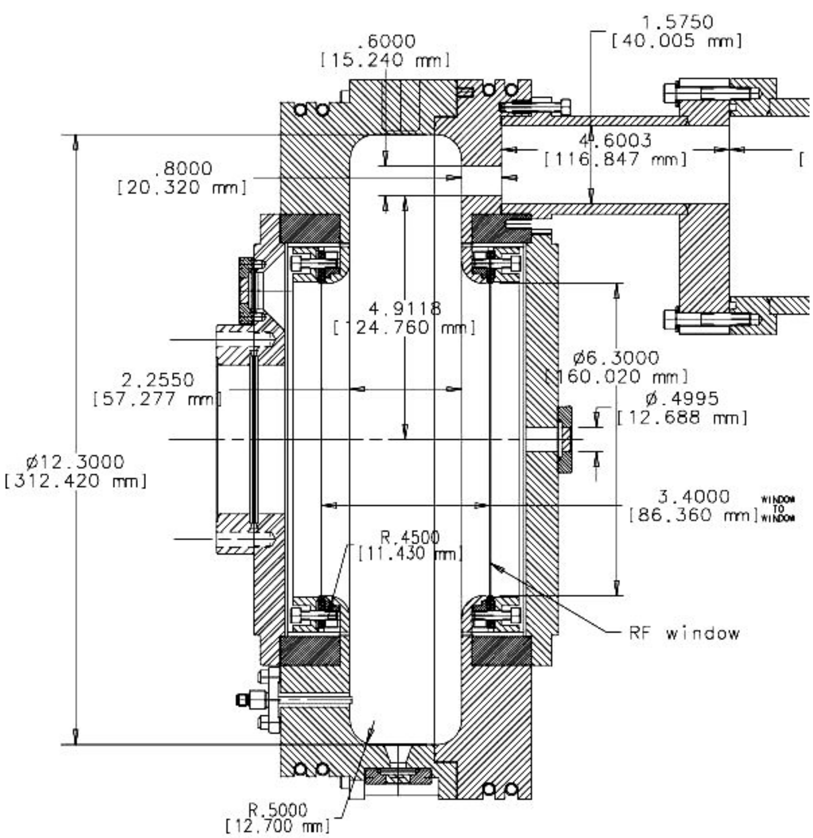
How can we do it?
  Build a test assembly

Timeline

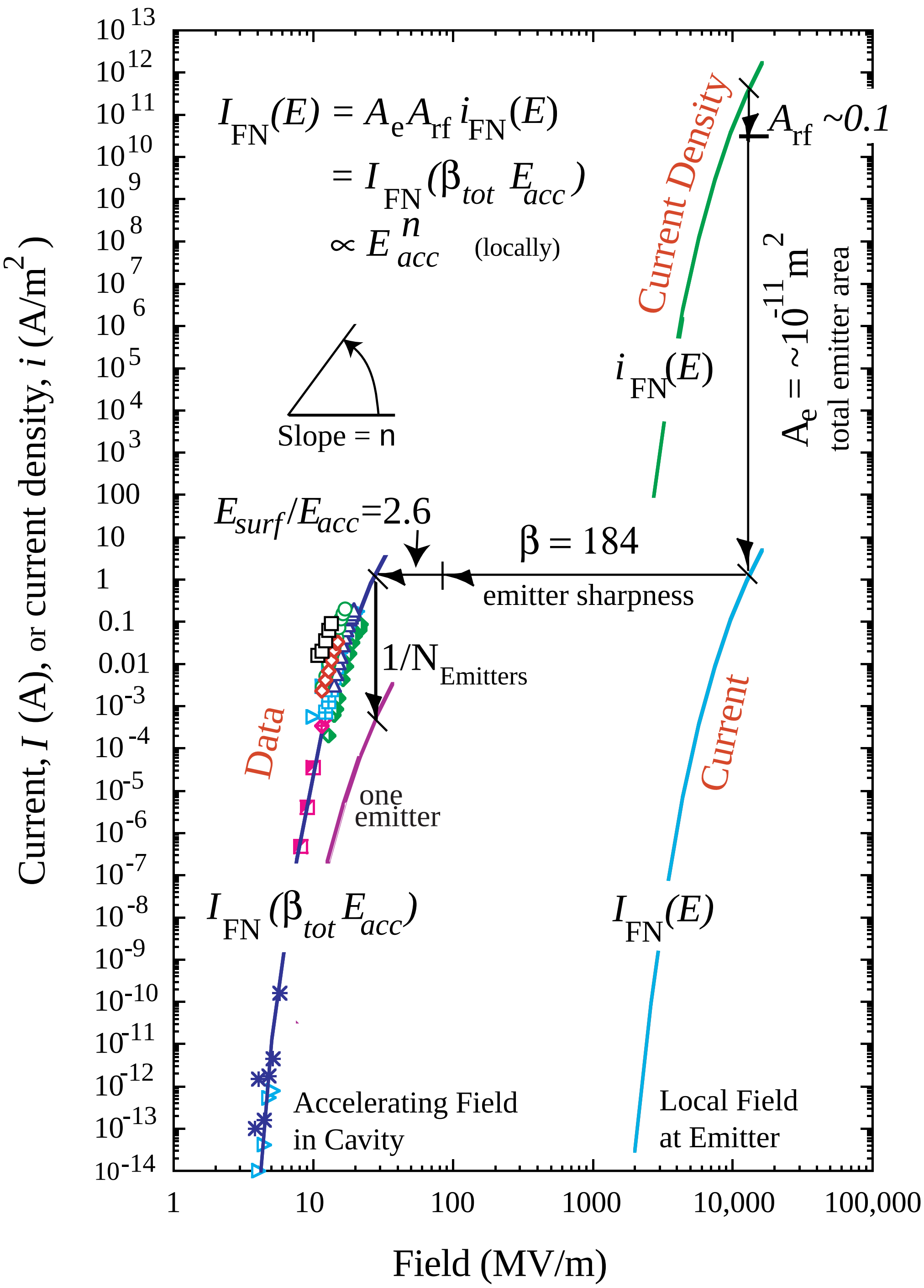
6/22/01	First measurements of dark currents in open cell cavity
12/20/01	Remove open cell cavity from magnet
1/4/02	Open Cell cavity removed from the Magnet
3/13/02	Begin conditioning with thick Cu plates
	Eventual operation at 34 MV/m, little sparking
7/16/02	Removal of thick Cu plates, little damage
7/30/02	Conditioning with thin Cu plates to 24 MV/m
9/27/02	Operation in B Field, high BG, E_{max}=16 MV/m
	Improvements from conditioning with B=0
12/5/02	Removal of thin plates, considerable pitting
12/19/02	Conditioning of TiN/Be windows to 21 MV/m
2/10/03	Begin conditioning with B field
	Conditioning to 17 MV/m, stable at 14 MV/m
4/22/03	Replacement of Be windows
6/1/03	Through multipactoring regime, begin HV conditioning.

Pillbox cavity Window materials

Rf window	Cu	Cu	Be
Thickness	0.200"	0.015"	0.01"
(g/cm^2)	4.55	0.342	0.045
Vacuum window	SS	Ti	Ti
Thickness, (g/cm^2)	15	0.091	0.091
E_{rf}/V_{probe} (MV/m/V)	1.49	1.28	1.16
Maximum gradient	34	23	16
E_{surf}/E_{acc}	1.01	1.01	1.01

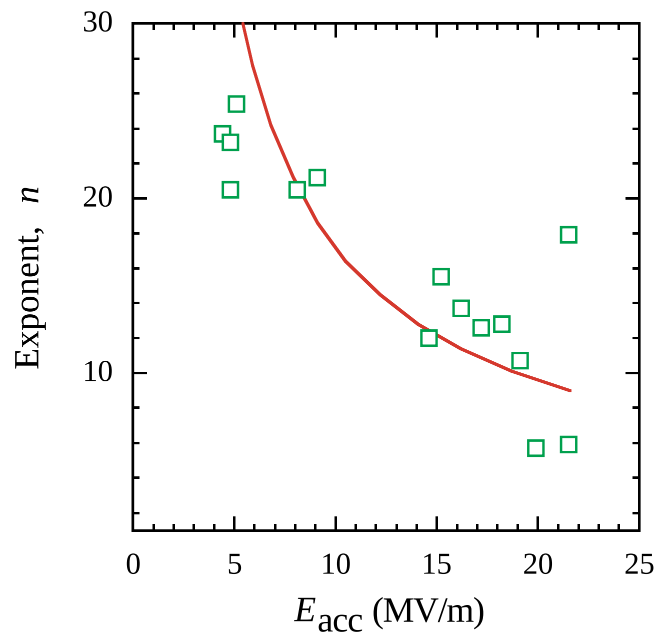


What have we learned?

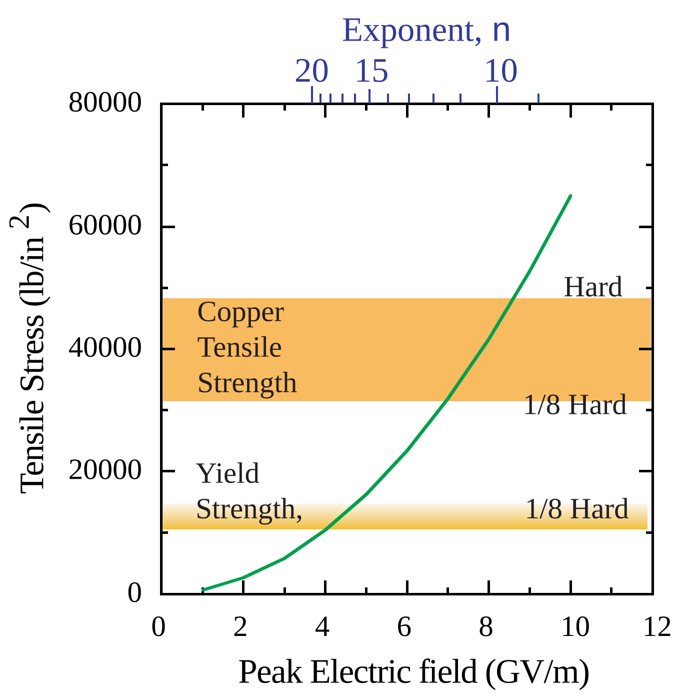


A new way of looking at dark currents

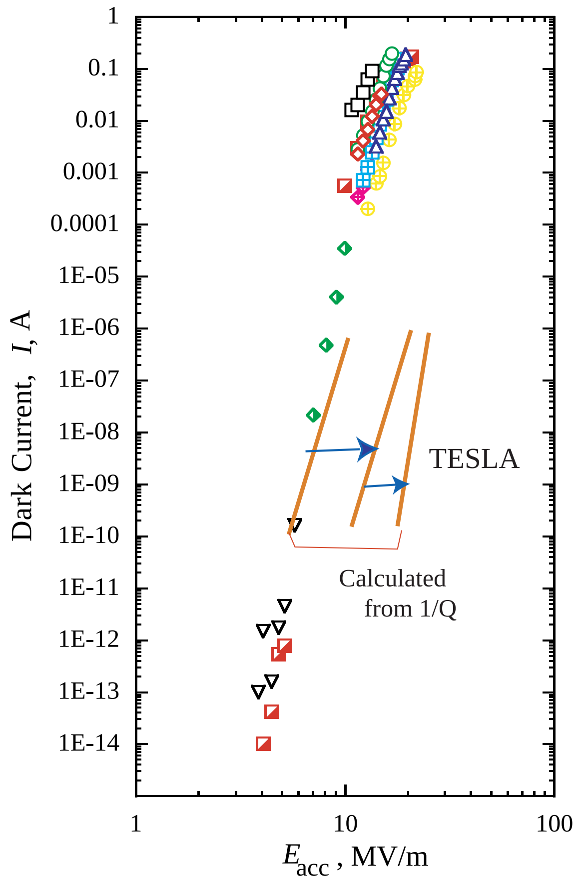
Fowler-Nordheim emission tells us $E_{emitter}$

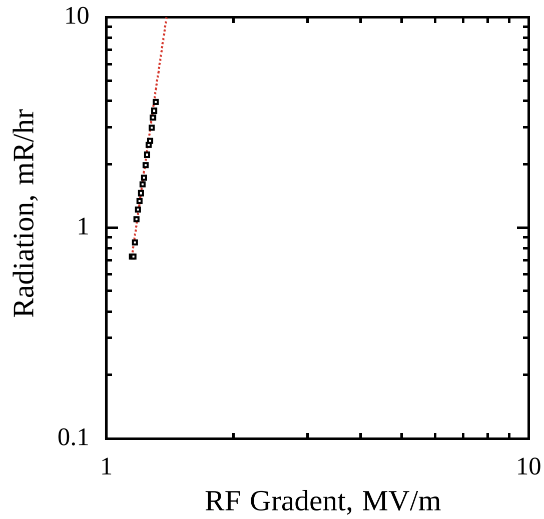


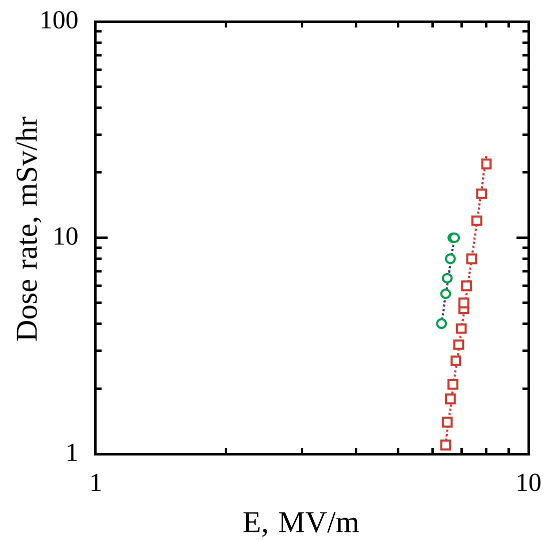
which we can use to predict Breakdown.

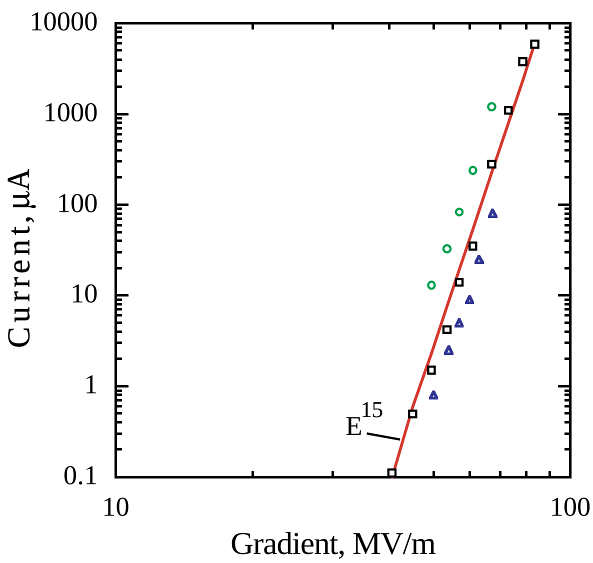


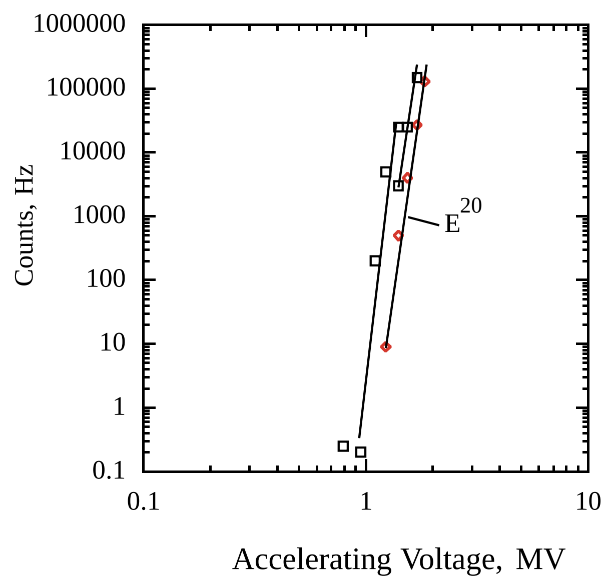
Other structures see the same effects.



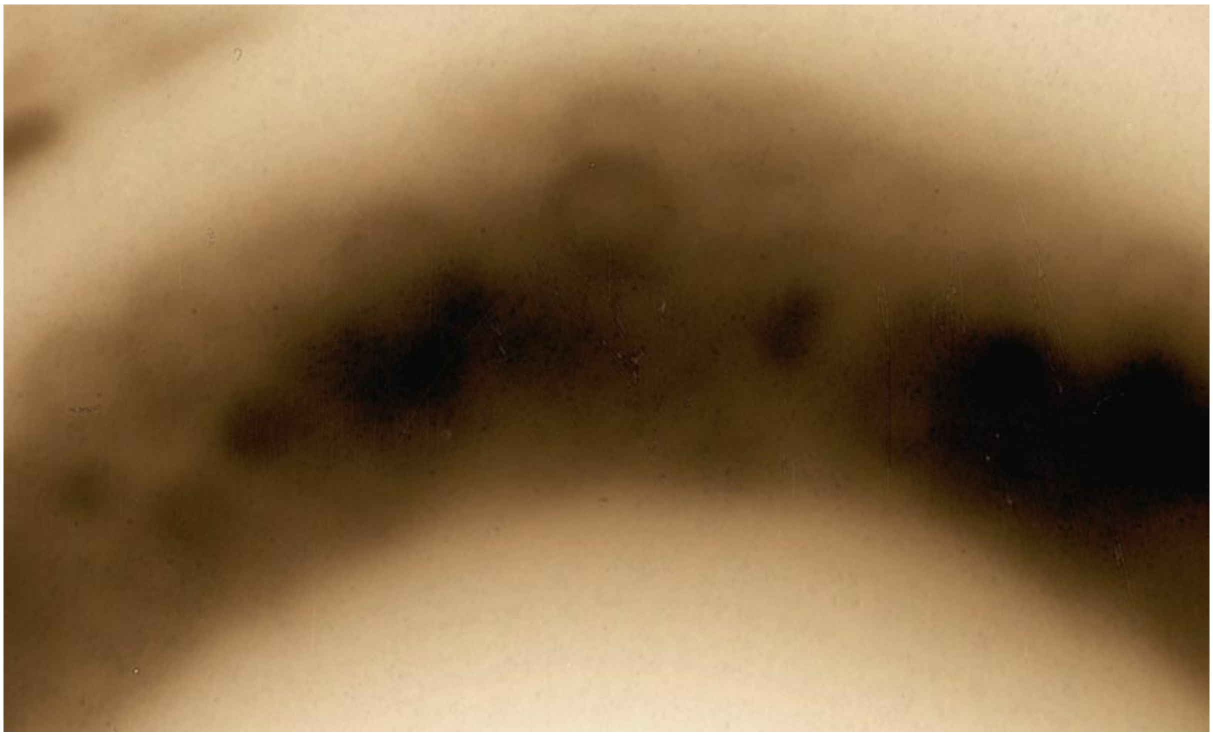


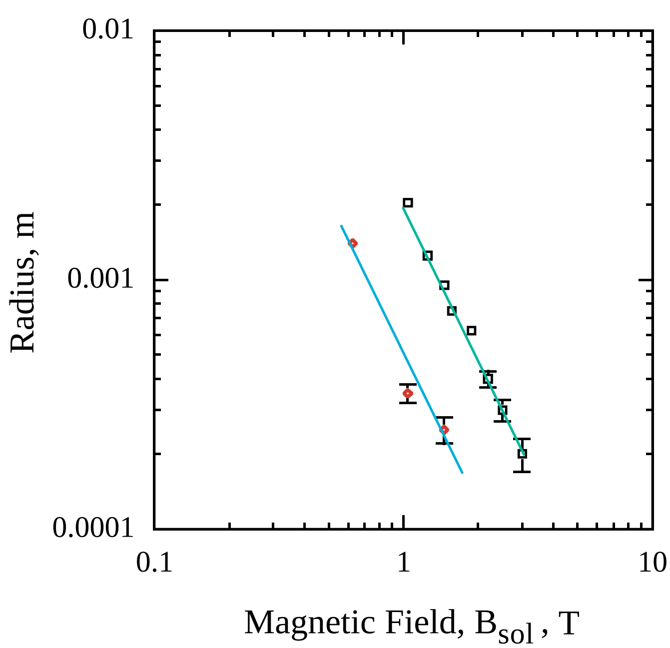


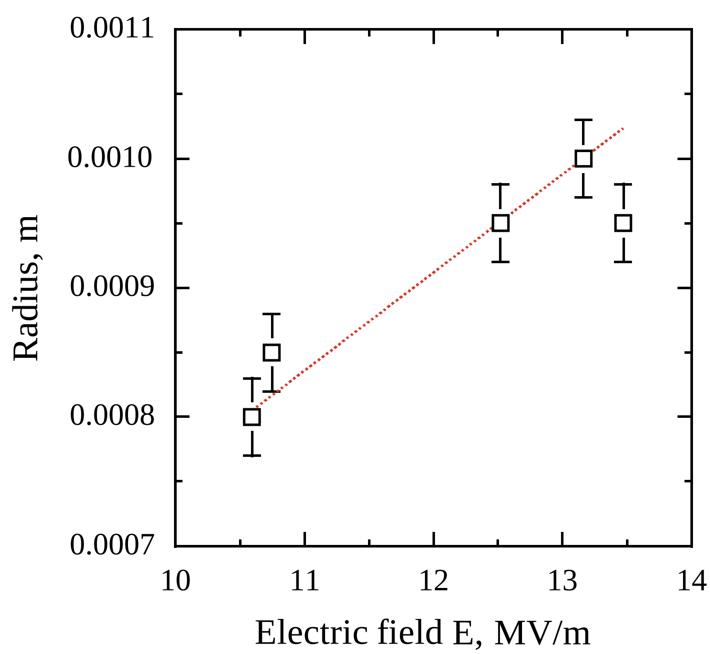




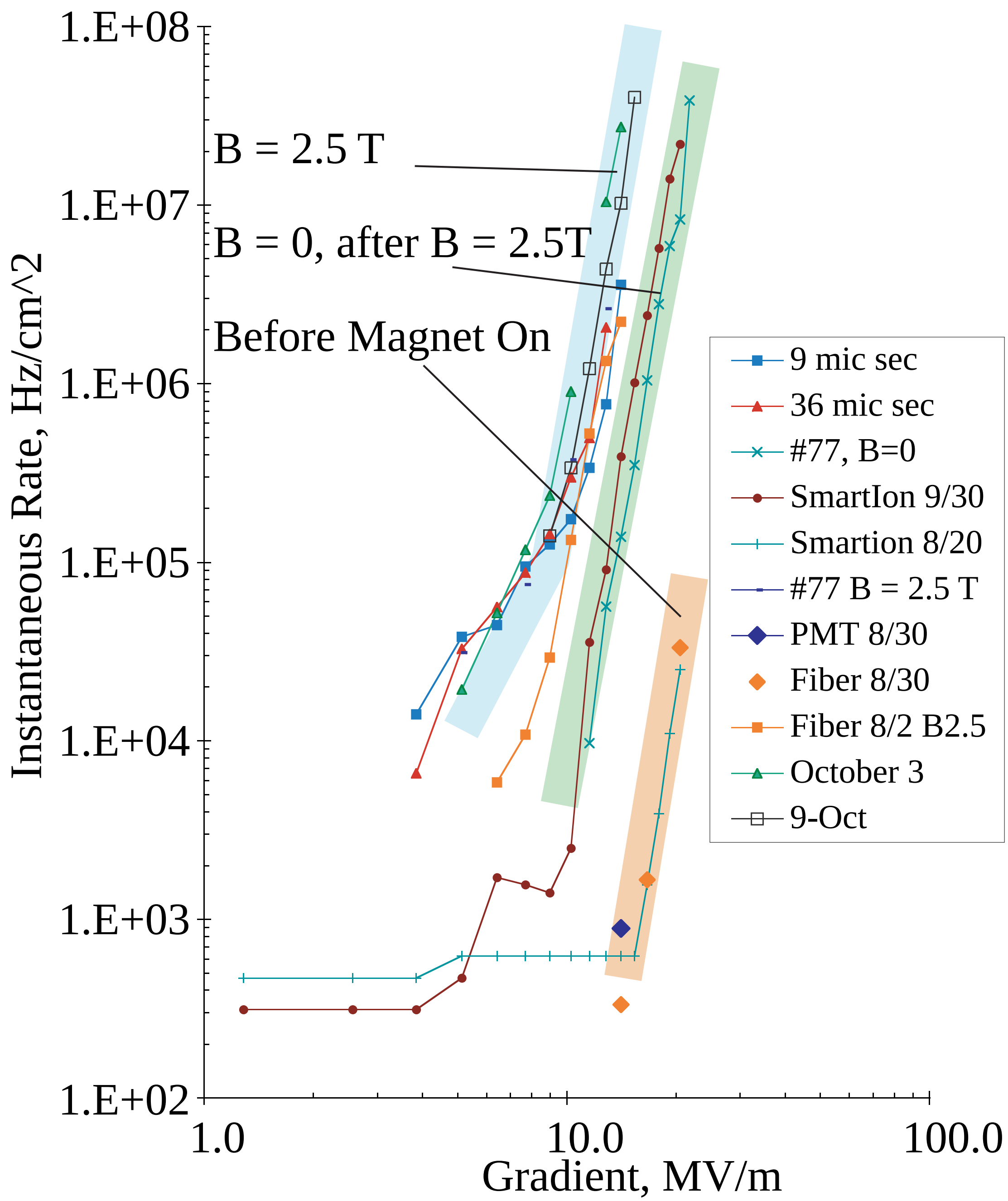
We saw ring beamlets.





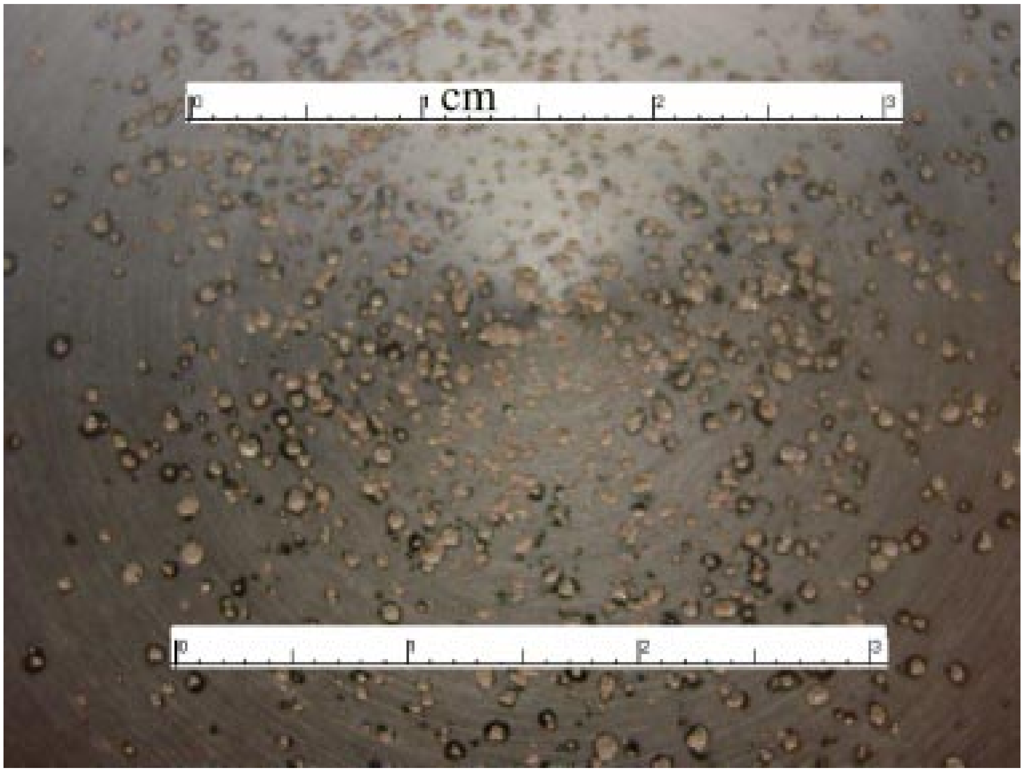


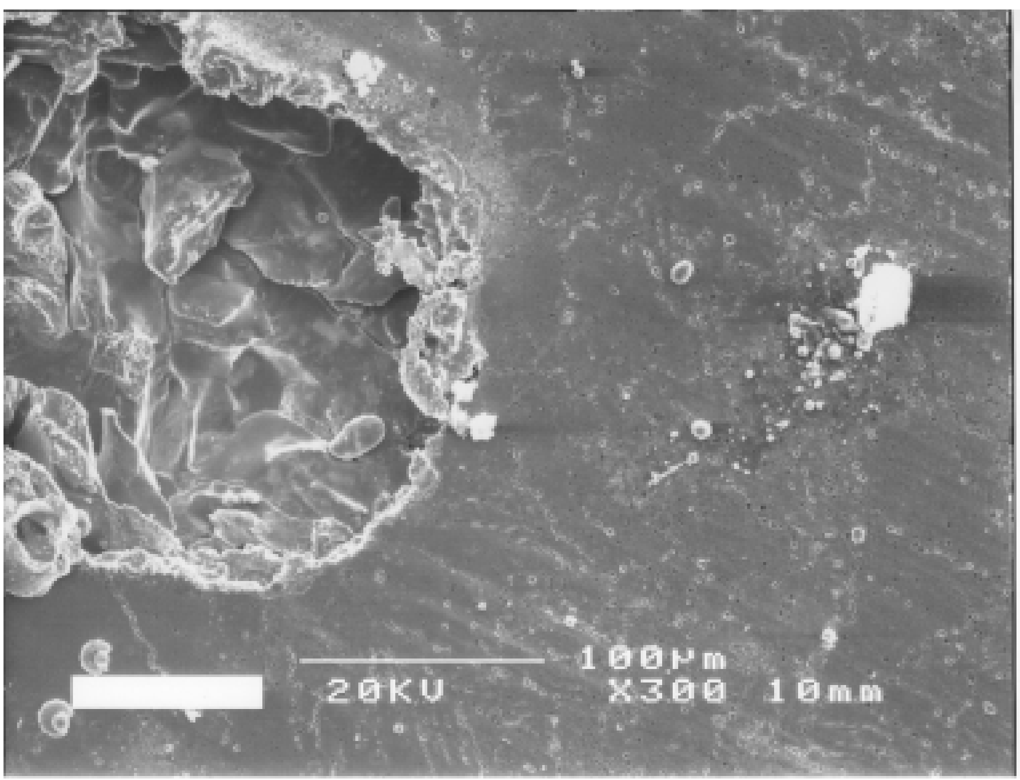
The Rates Were Higher with the Magnet On



They stayed high when the magnet was turned off, although a long period of conditioning seemed to heal the damage.

Copper Plate: Optical and SEM

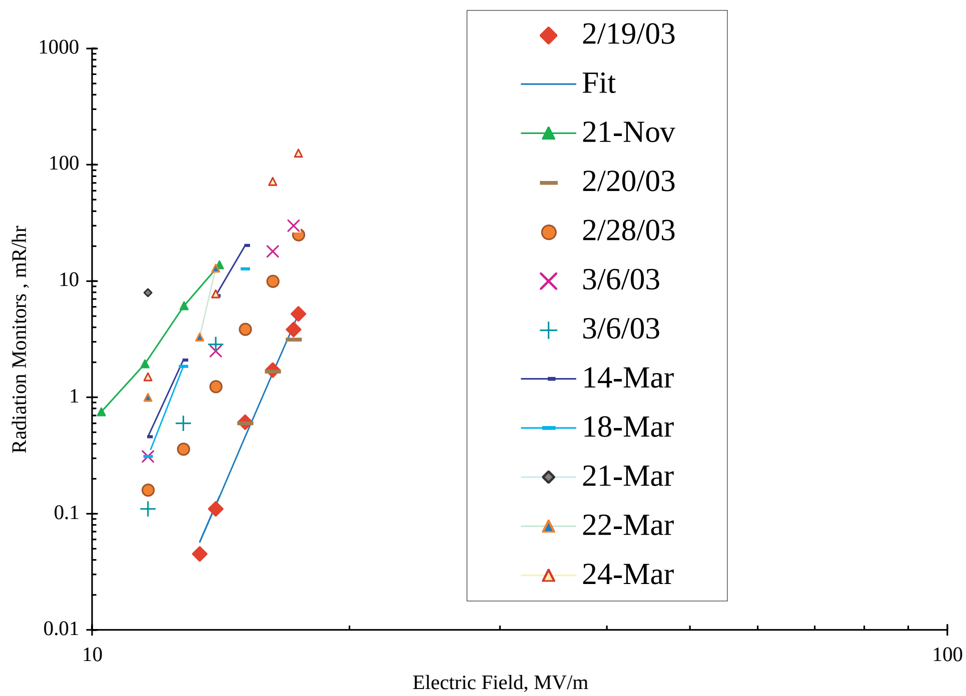




many pits about 200   400 microns in diameter

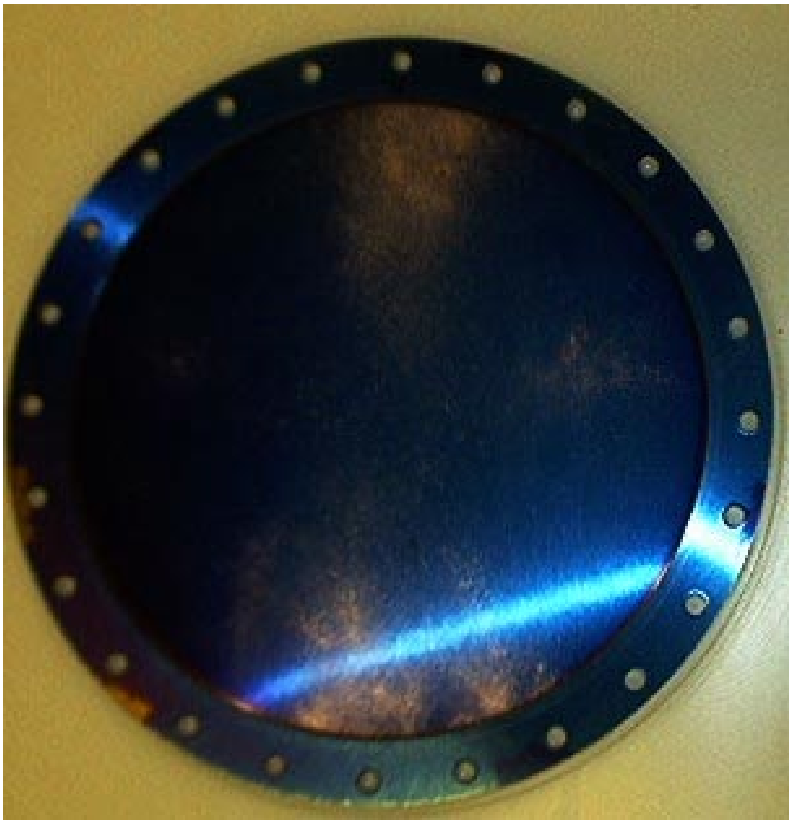
The Be data Didn't good at first

When the cavity first came on the rates were reasonable, but the longer we ran, the more the rates seemed to drift upward. Most of these problems seemed to come late in the run.



The Problem was Copper Splashes on Be

The window looked as if it has been dusted with copper.

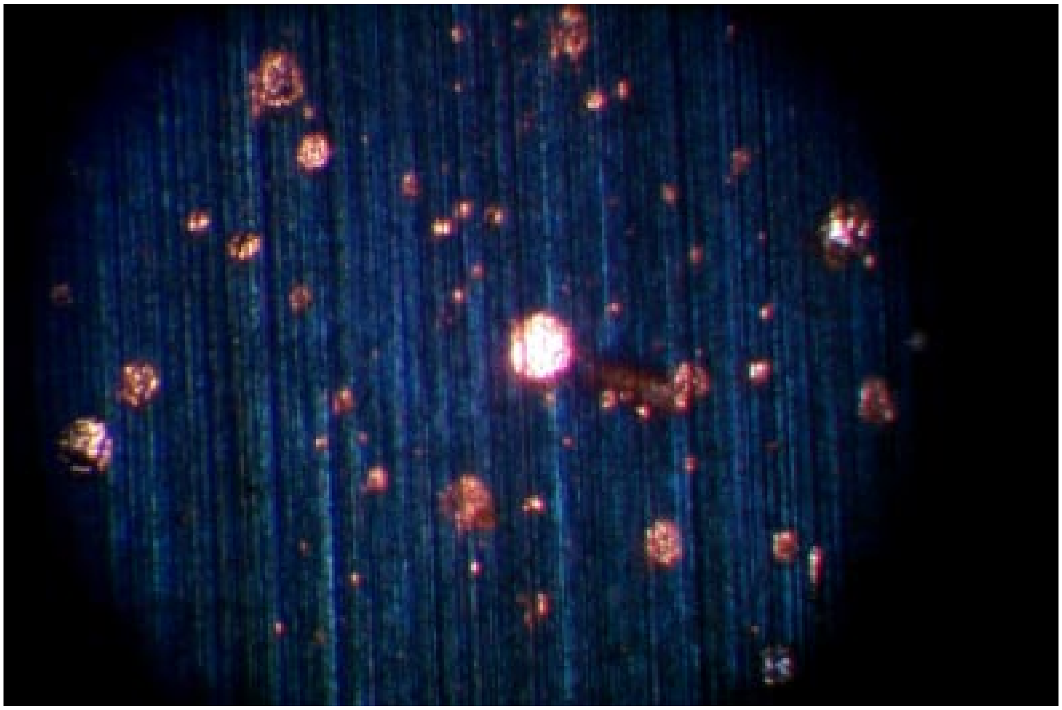


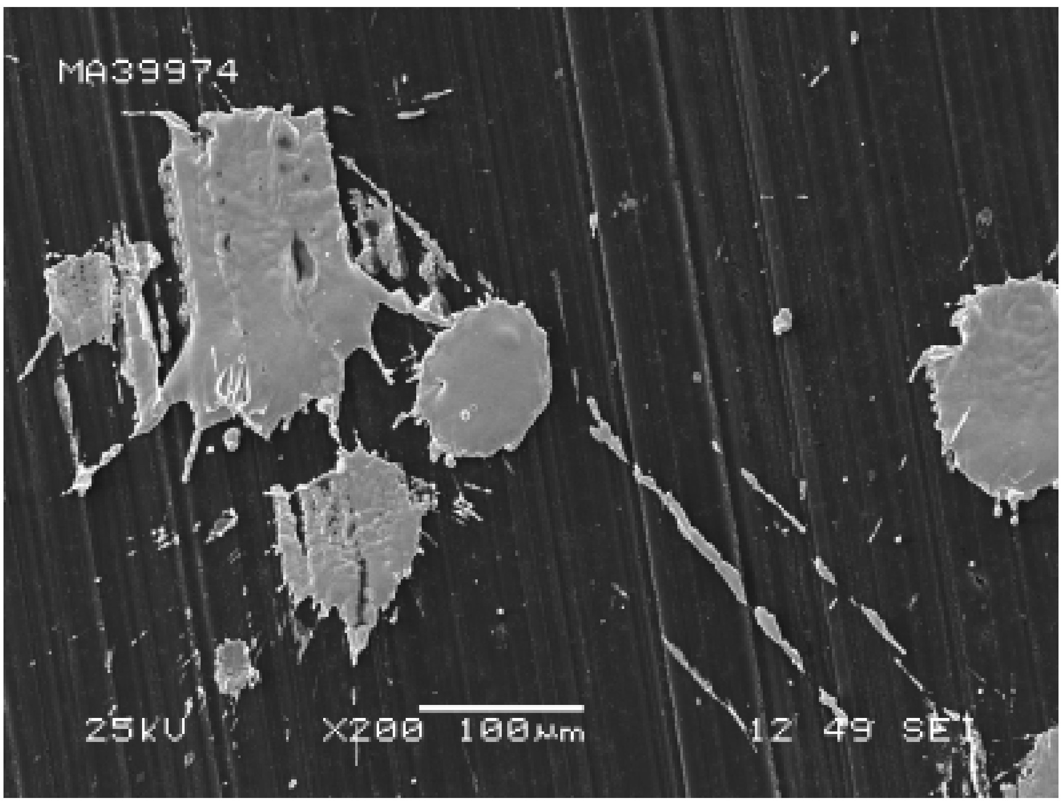
We could see the individual emitters forming.

Most of the field emission seems to have come from the copper, and we expect it to go away if we can find a way to prevent arcs in the copper.

There seems to have been no damage to the Be, either seen with optical or SEM systems.

Be Plate: Optical and SEM

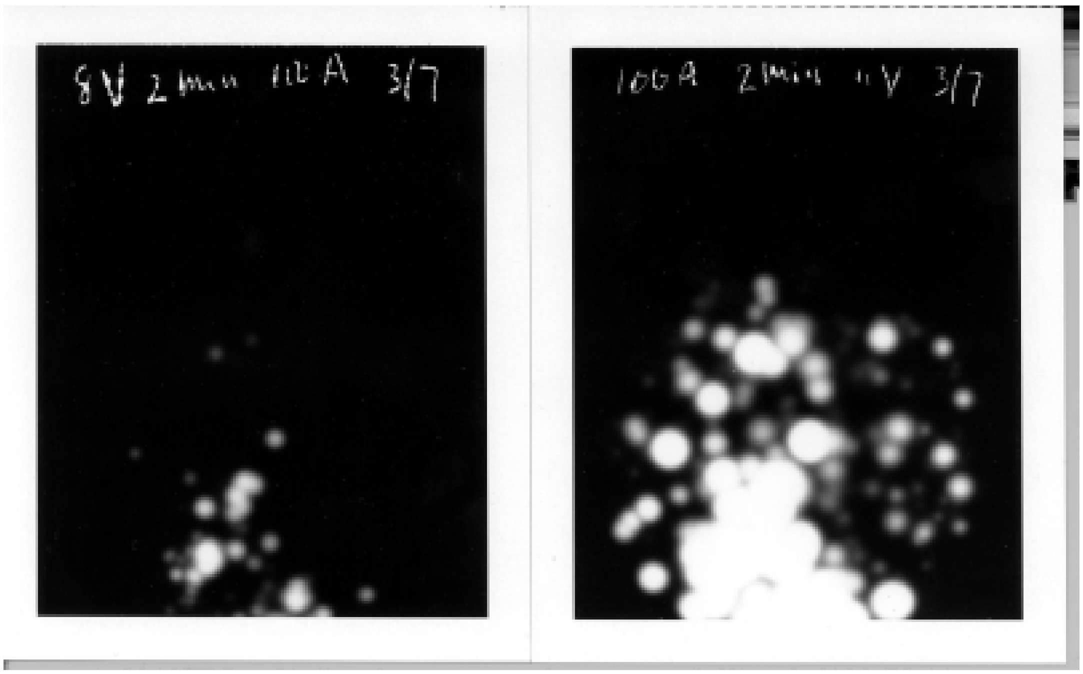




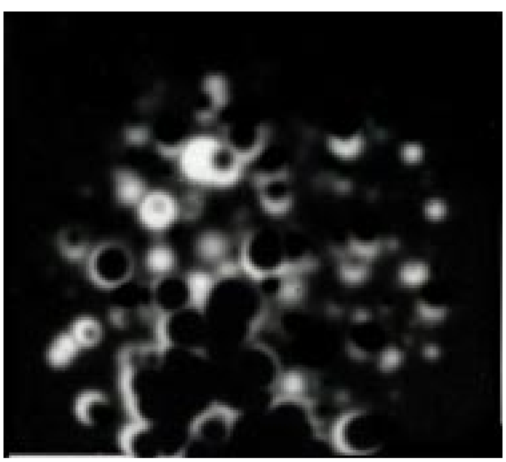
Lots of copper droplets - **no damage to Be*!!***

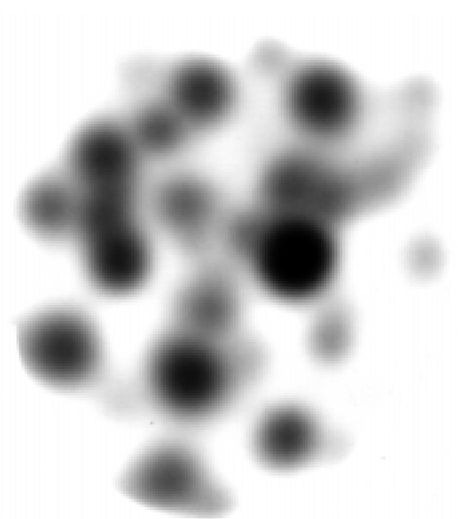
We can look at individual emitter beams

Polaroids give a closeup (two rf fields)



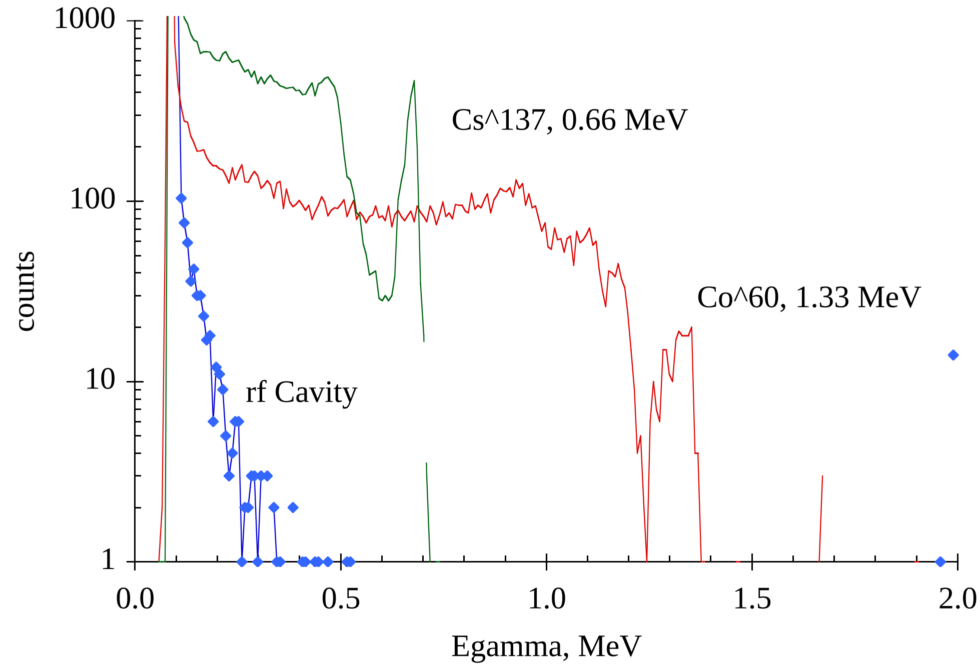
We can subtract data from one day
to the next and see changes.





and see the divergence of the
beams with photographic paper.

We have energy spectra of X-Rays



The spectra are not directly from low energy bremsstrahlung and show characteristics of scattering.

Be Compares Well with Cu

	Be	Cu	
Tensile Strength	510	320	Mpa
Melting Pt	1380	1270	degC
Conductivity	3.6	1.7	μOhm cm

We are hosting a Workshop

Workshop on High Gradient RF

Argonne National Laboratory

October 7 - 9, 2003

High energy physics and other sciences use rf structures for charged particle acceleration, and are actively engaged in trying to extend the gradient limits of these devices. Although the limits on high fields in rf cavities have been studied for many years, there is still some ambiguity as to what causes breakdown and other phenomena that limit the ultimate gradients of these devices, for example surface pulsed heating. The purpose of this workshop will be to review recent experimental results as well as relevant theoretical models. We hope to have active participation from the rf community, as well as significant input from those doing materials science and numerical modeling. Although the primary focus of the workshop will be on normal conducting structures, we would hope the discussion would be relevant to high gradient rf guns, high power klystrons, high voltage breakdown and superconducting rf.

The goals of the workshop will be to: 1) identify the mechanisms limiting rf gradients, 2) discuss the use of new materials and techniques, 3) improve modeling and experimental predictions, and 4) consider possible experiments and collaborations.

all details at: http://www.hep.anl.gov/rf/

What do we still need to know?

Be seems to work, but we need to understand how to keep the copper from contaminating it.

We want to know what other materials can be used in cavities, ideally on a time schedule fast enough for mice.

There seems to be no information on the long term stability of any surface other then copper. We would like to know about Be, TiN, and a variety of other coatings.

What do we need to do now?

We are using this meeting to plan a test assembly for putting small samples in the cavities in Lab G and perhaps the Muon Test Area at Fermilab.

We are also developing a test program to begin testing using this assembly.

Summary

Although the fields of rf breakdown and rf cavity design have been active for many years, there was little relevant information for muon cooling.

In two years at Lab G we have started to learn how these cavities will behave in our environment. In particular we have studied

- Stored energy
- Magnetic field
- Be surfaces
- Breakdown limits
- Optics of dark current beams
- Background levels for MICE.

This effort also includes a new theory of breakdown in cavities.

We need to extend this work specifically to the 201 MHz cavities for MICE.